Warm Dense Matter – getting a grip at a hot topic

October 18, 2016

The first cutting edge simulation of the warm dense electron gas

An international team of scientists from Los Alamos National Laboratory, the London Imperial College, and Kiel University (CAU), headed by Professor Michael Bonitz from the Institute of Theoretical Physics and Astrophysics of CAU, has achieved a major breakthrough in the description of warm dense matter – one of the most active frontiers in plasma physics and material science, particularly for inertial confinement fusion research.

This exotic state of matter is characterized by the simultaneous presence of quantum degeneracy, thermal excitations, and interaction effects, which means that it differs completely from the usual solid, liquid, gas or plasma states commonly found on Earth. In particular, the non-trivial interplay of these physical effects has, so far, precluded precise theoretical predictions.

“These new results provide for us, at previously unavailable accuracy, the necessary input required to create much better simulations of warm, dense matter,” said Travis Sjostrom of Los Alamos’s Theoretical Division, one of the researchers on the project.

As suggested by its name, warm dense matter exhibits an extremely high density of up to a thousand times higher than that of normal solids and temperatures exceeding ten thousand times room temperature. These extreme conditions have long been predicted to exist within astrophysical objects such as planet cores and white dwarf atmospheres. “An improved understanding of warm dense matter will be the key to answer fundamental questions in astrophysics. For example, it will help to determine the age of galaxies,” explains Bonitz.

These days warm dense matter conditions are routinely realized in the lab in laser-excited solids for time scales up to microseconds, which has sparked an explosion of activity in the field. In particular, researchers need to overcome the challenges arising from this extreme state of matter in order to master inertial confinement fusion, which is considered to be the most promising source of energy in the future.

Until now, a theoretical description of warm dense matter has only been feasible by introducing crude approximations of the underlying physics. On the other hand, exact simulations have been developed, but they were restricted to small model systems containing only a few particles in a limited parameter range. The research team around

Bonitz has overcome these obstacles by combining two complementary simulation techniques, recently developed in Kiel, in combination with a novel approach to extrapolate the results from a finite model system to the infinite macroscopic limit. With this they were able to report the first accurate thermodynamic results of the electron component in warm dense matter. The performed simulations required an enormous amount of computer resources, such that, if carried out on a single desktop computer, it would have taken about 200 years.

The trinational team of scientists published their research findings in a recent edition of the journal *Physical Review Letters*.

Video Link: Understanding the microscopic properties of dense, strongly coupled plasmas and their consequences on macroscopic properties through analytical theory and numerical simulations